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Title: Microstructure Evolution of Beryllium Subjected to Shear-Compression  
Investigated Using Synchrotron X-Ray Diffraction

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# Microstructure Evolution of Beryllium Subjected to Shear-Compression Investigated Using Synchrotron X-ray Diffraction

T.A. Sisneros<sup>1</sup>, D. W. Brown<sup>1</sup>, B. Clausen<sup>1</sup>, C.M. Cady<sup>1</sup>, C. Liu<sup>1</sup>,  
H. M. Mourad<sup>1</sup>, and J. Almer<sup>2</sup>

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<sup>2</sup>Argonne National Laboratory, Argonne, Illinois

# Abstract

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## **Microstructure Evolution of Beryllium Subjected to Shear Compression Investigated Using Synchrotron X-Ray Diffraction**

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**<sup>1</sup>Los Alamos National Laboratory, Los Alamos, New Mexico**

**<sup>2</sup>Argonne National Laboratory, Argonne, Illinois**

### **ABSTRACT**

An experimental investigation was carried out to study the stress (strain) state and dominant deformation mode in the gage section of shear compression specimens (SCS) of both textured and randomly textured polycrystalline beryllium. Due to the low crystal symmetry, beryllium, like most other hexagonal metals, must deform using a host of deformation modes, including dislocation slip and mechanical twinning. As consequence, beryllium is very brittle in tension at room temperature. SCS have two opposed slots machined at 45° with respect to the longitudinal axis, thus forming the test gage section. The spatial variation of the lattice strains over the gauge section was measured in situ using synchrotron X-ray diffraction. Significant ductility was observed for both conditions as well as twinning activity.

# Motivation for Work on Beryllium

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- LANL has a programmatic interest in beryllium.
- Fundamentally, beryllium is interesting because of the low symmetry structure and the inherent anisotropic behaviour.
- Beryllium has some interesting properties.
  - Modulus : 300GPa.
  - Strength can approach : 1GPa.
  - Density : 1.8g/cm<sup>3</sup>.
  - Poisson's ratio : 0.03.
  - Melting point : 1560K.
  - Thermal Conductivity : 190 W/mK.

**Alas, 2% of the population has a fatal  
“allergic” reaction to beryllium particulate.**



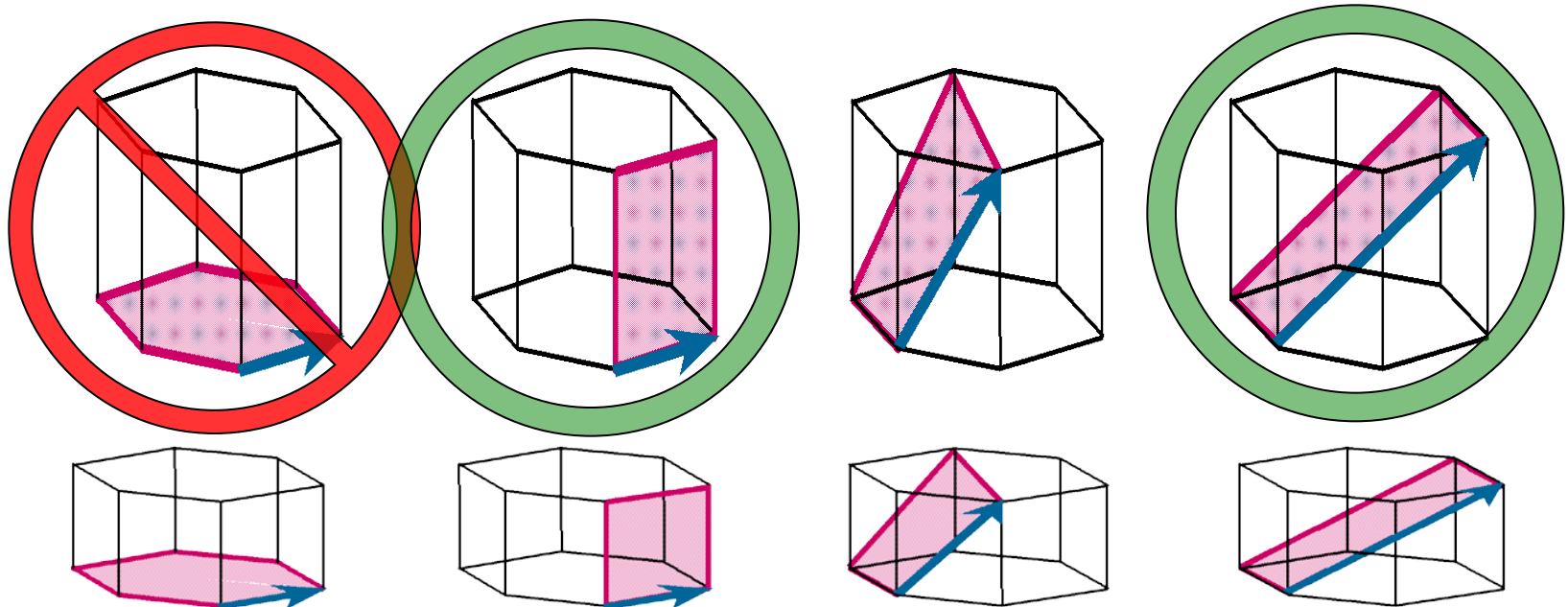
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# Low symmetry of hexagonal crystal allows control of deformation modes

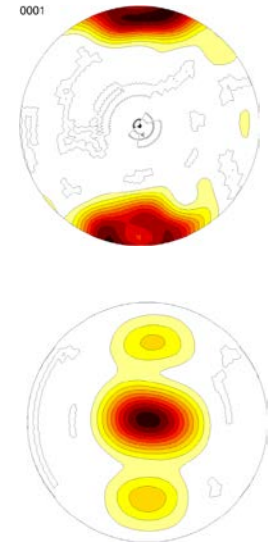
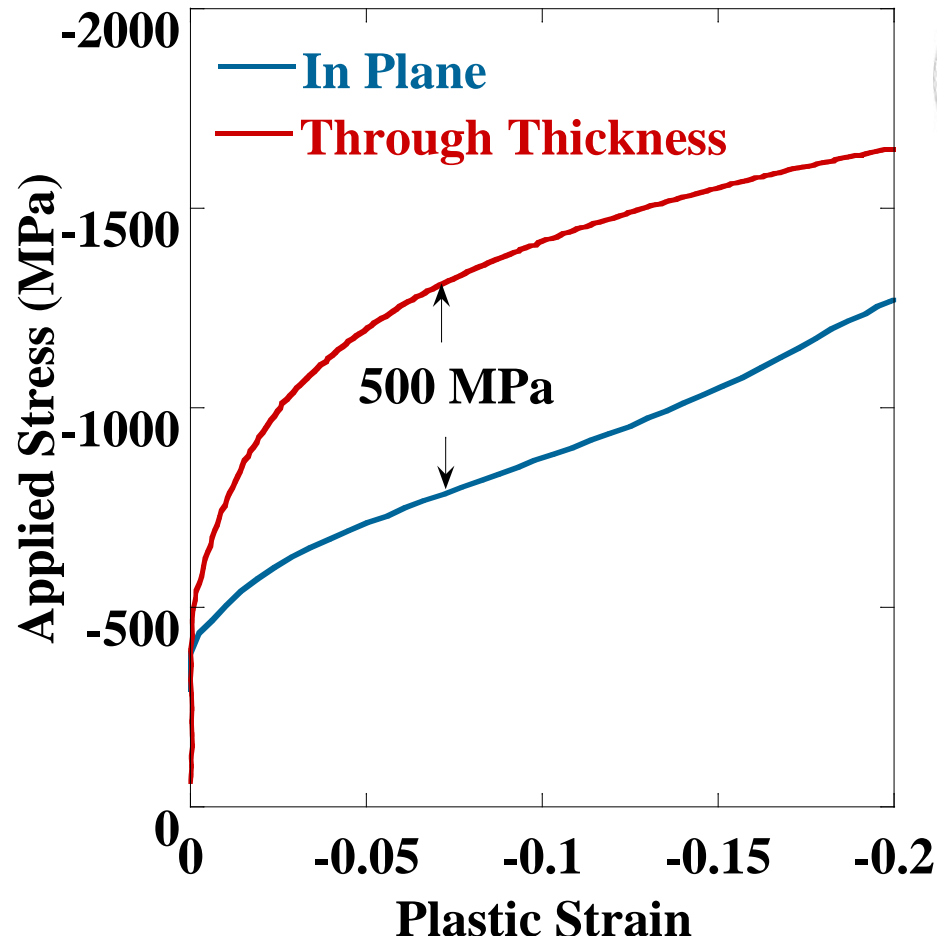
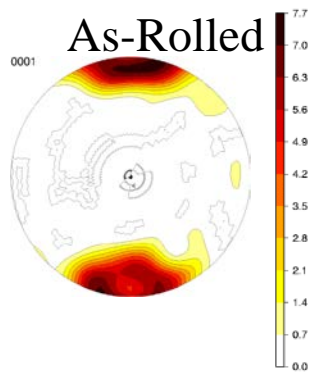


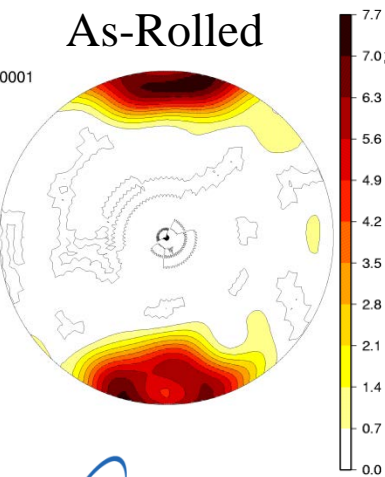
- Compressive strain transverse to the basal pole.
- Basal slip is off, Prismatic slip and tensile twinning are active.
- Balance between slip and twin modes affected by strain rate.

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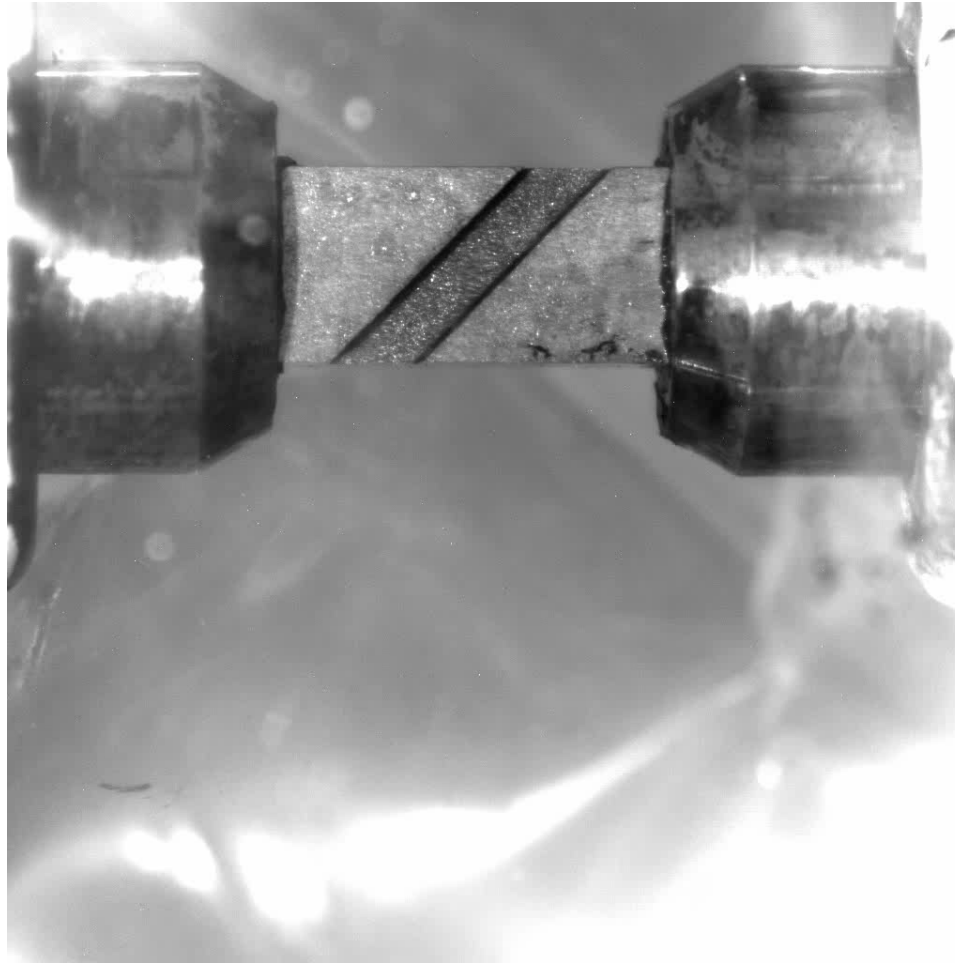
# The mechanical properties of beryllium can be very anisotropic



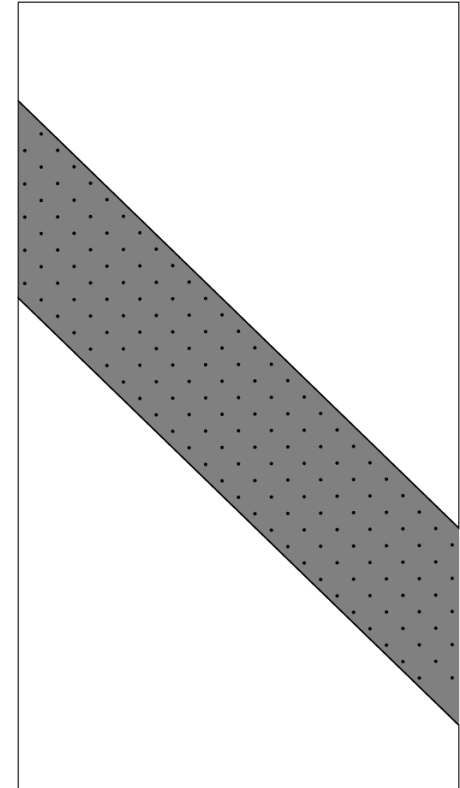
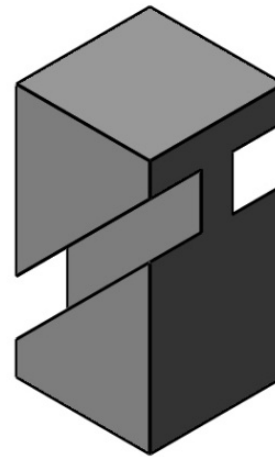
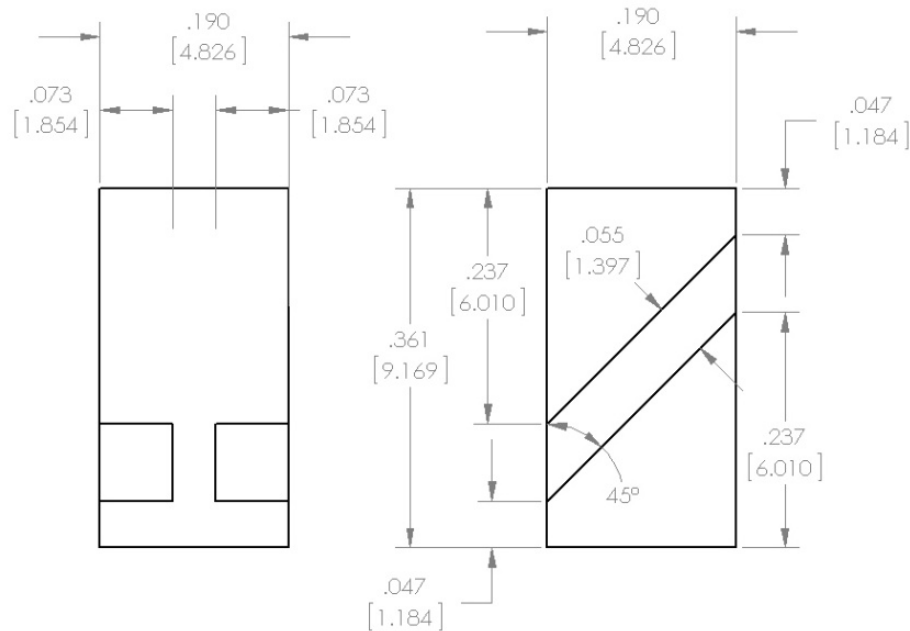


# Beryllium is brittle at room temperature in tension, ductility was observed in shear

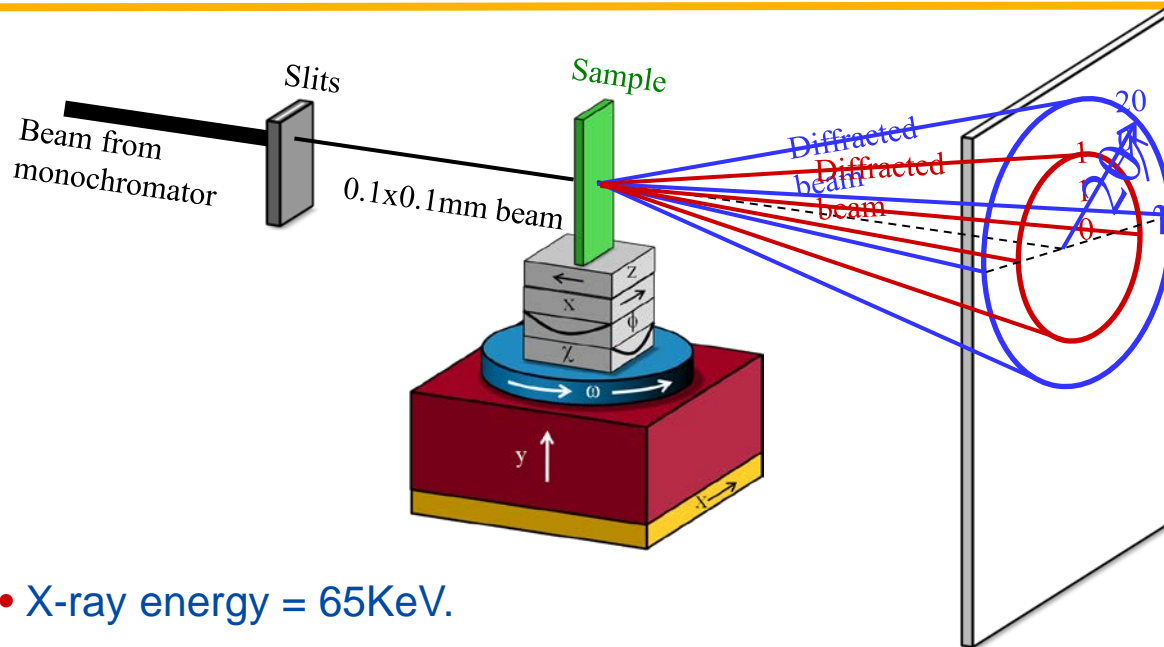
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# Non-uniaxial deformation data needed for model validation



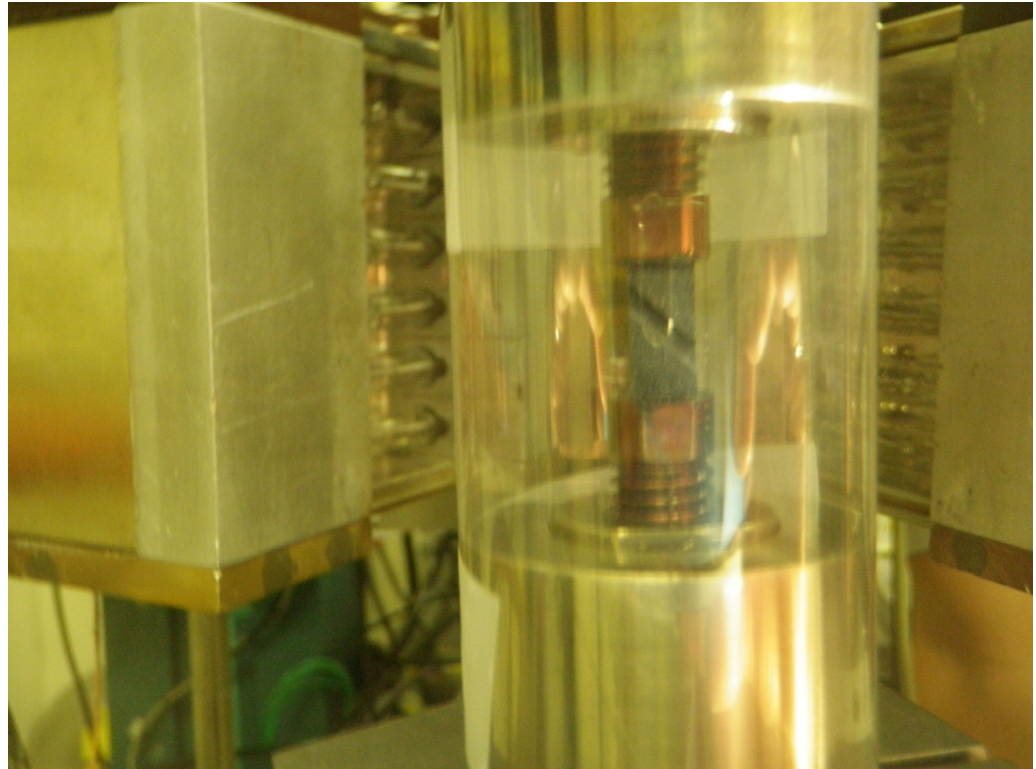
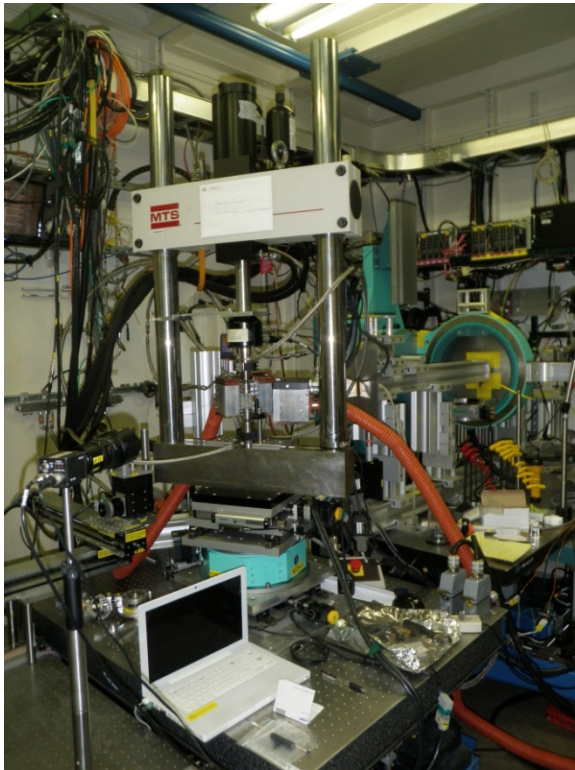
# Measurements on 1-ID at Advanced Photon Source



- X-ray energy = 65KeV.
- Beam cross section: 100mm X 100mm
- Collection time: seconds.
- Precision translation and rotation stages for mapping.
- 15kN load frame.
- ~1200C furnace.

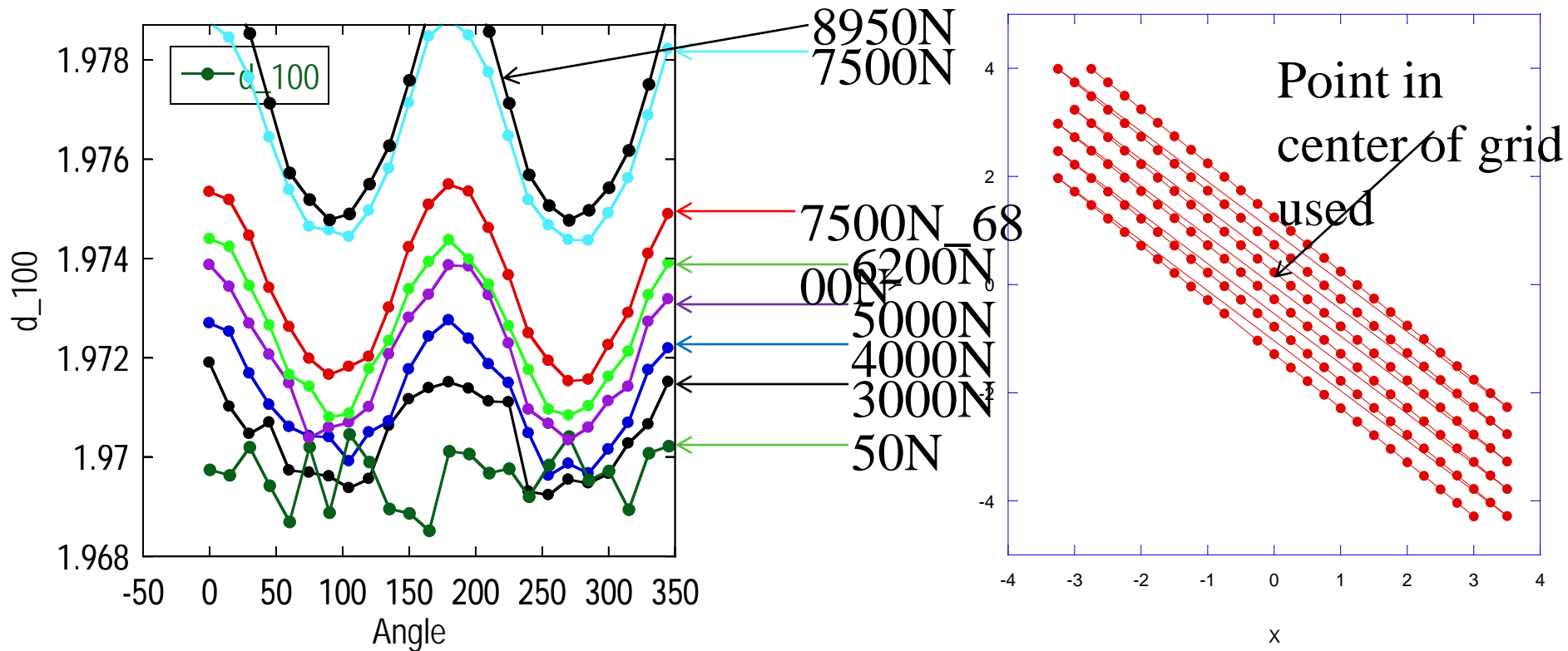
# We use in-situ diffraction to learn about deformation

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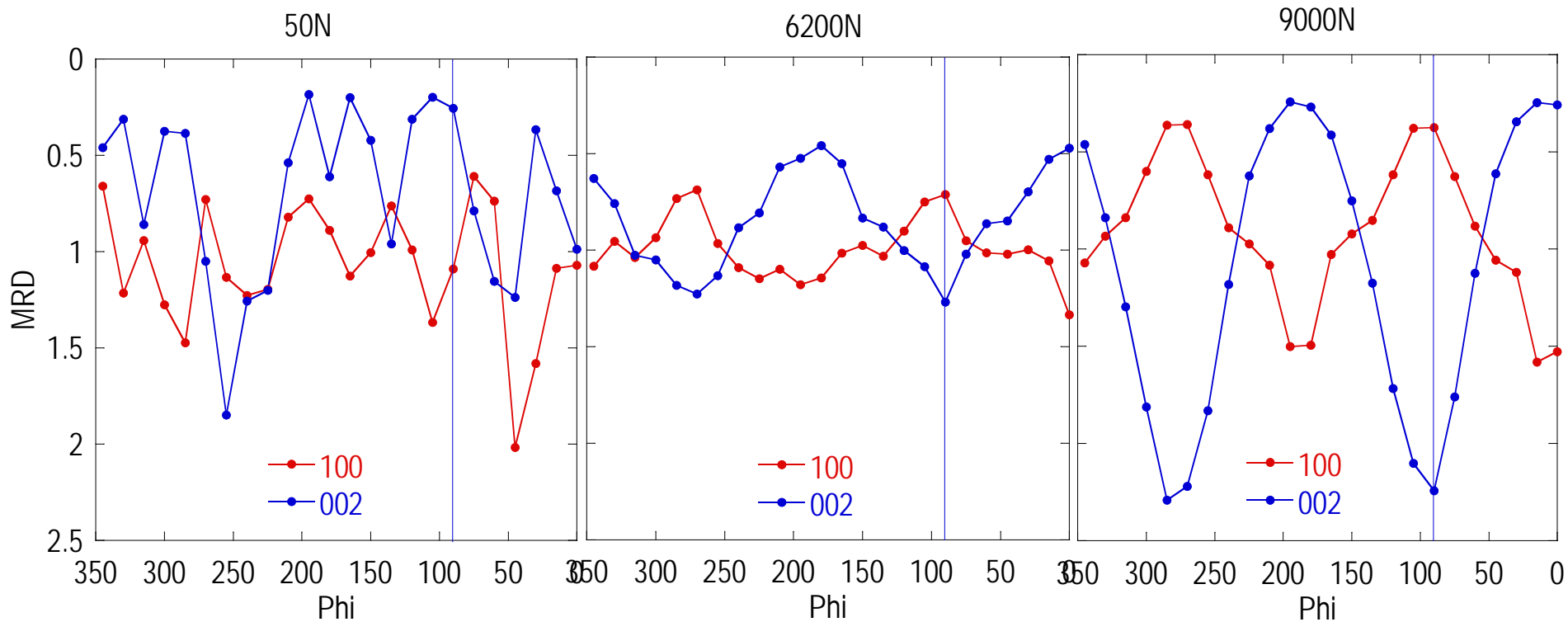




# We use in-situ diffraction to monitor microstructure evolution

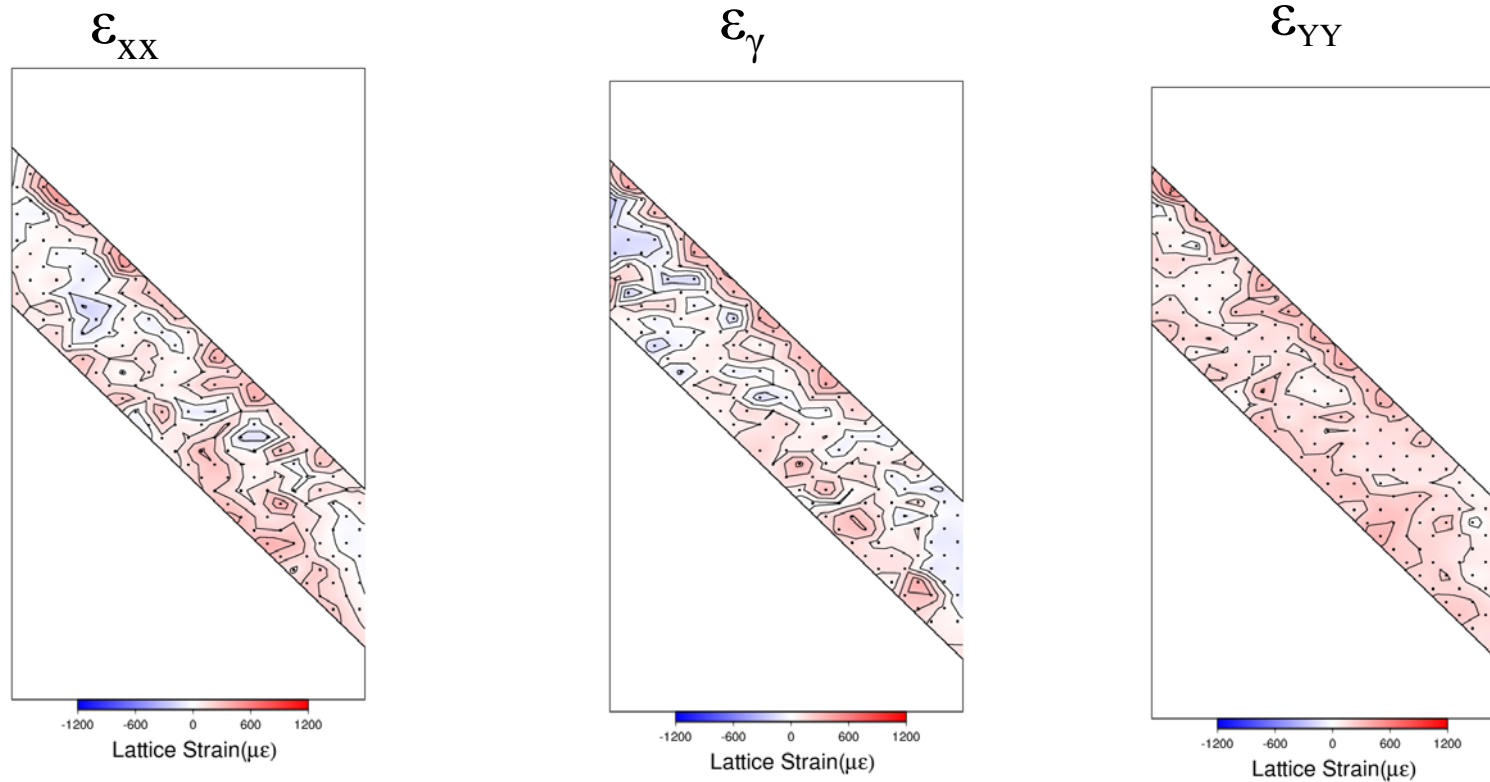


# We use in-situ diffraction to monitor microstructure evolution

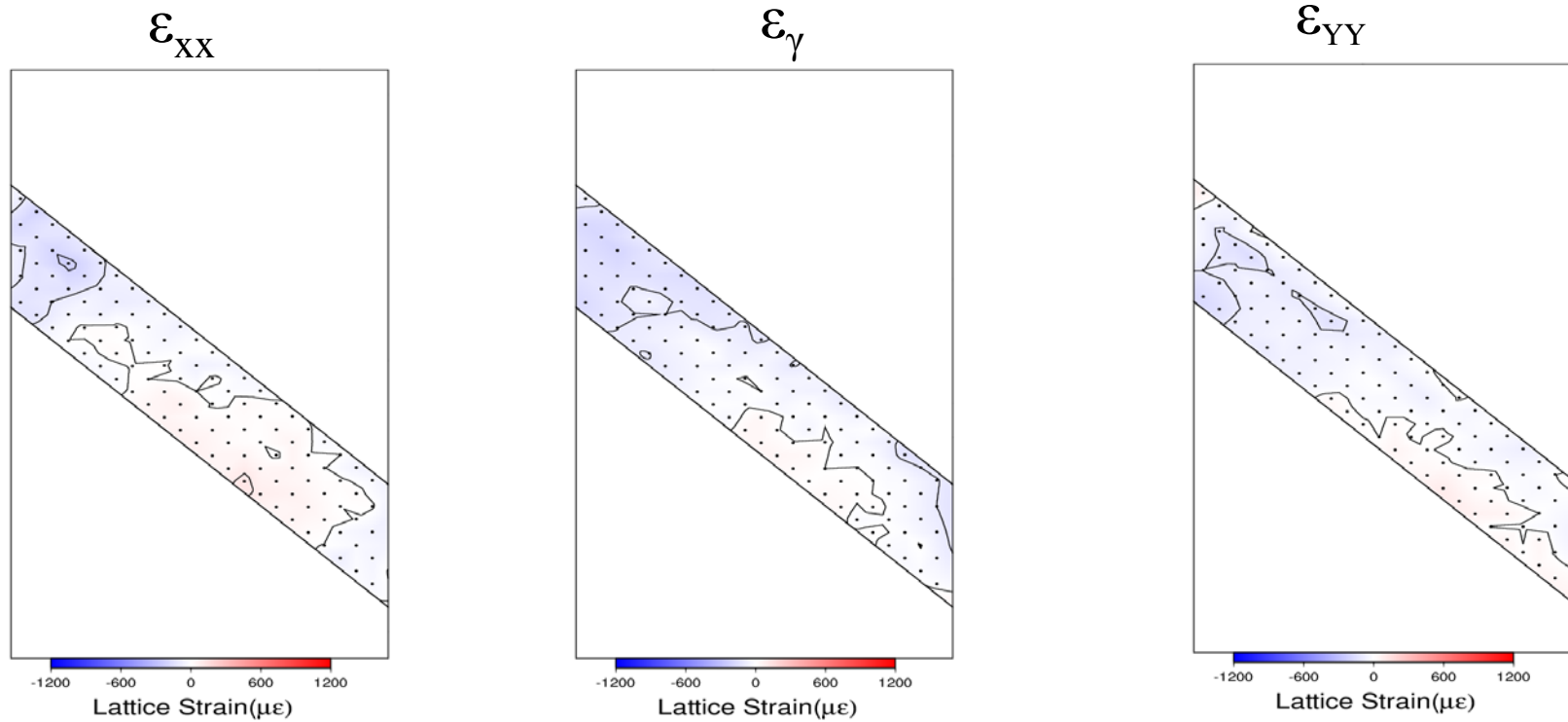




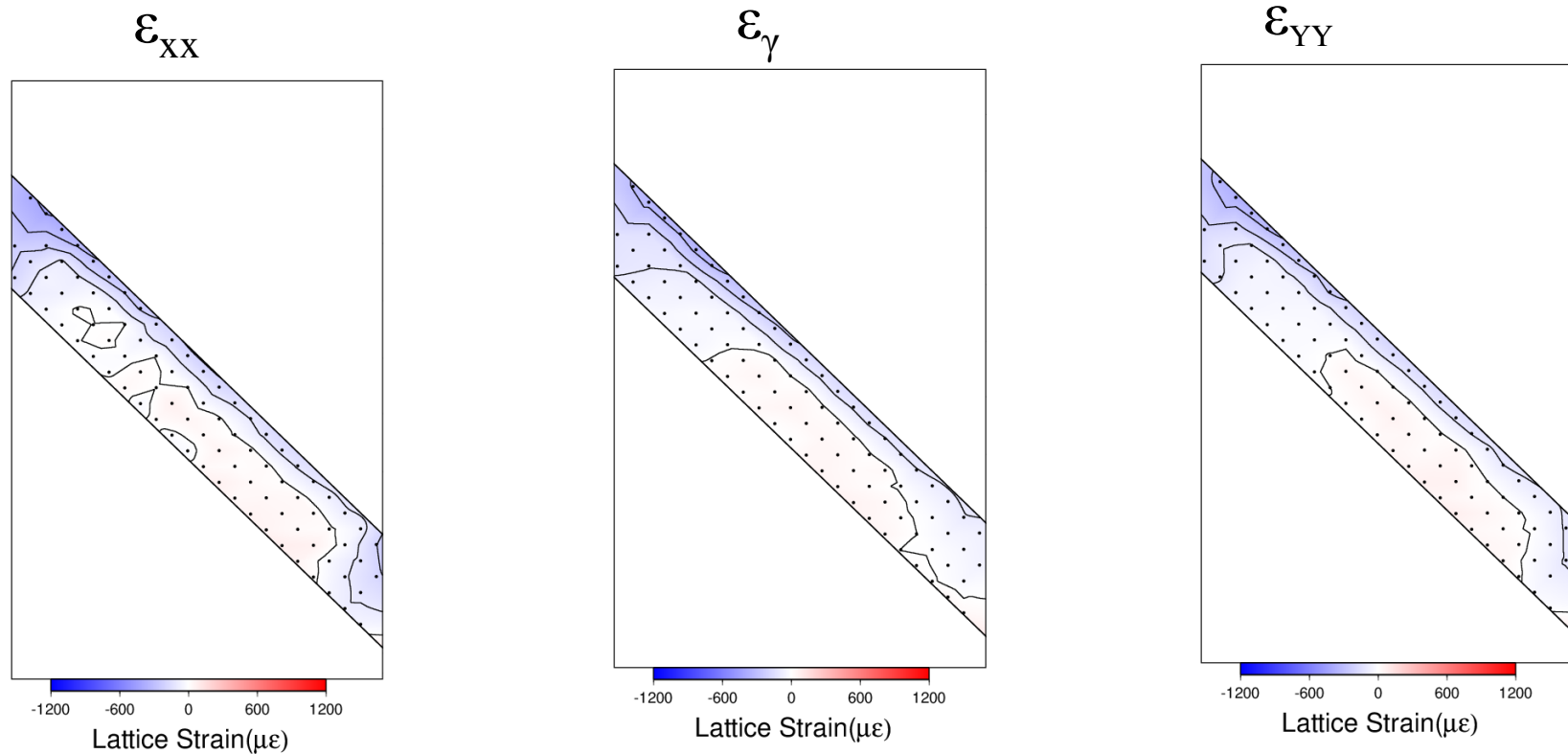
# Strain Distribution at 50N of Force



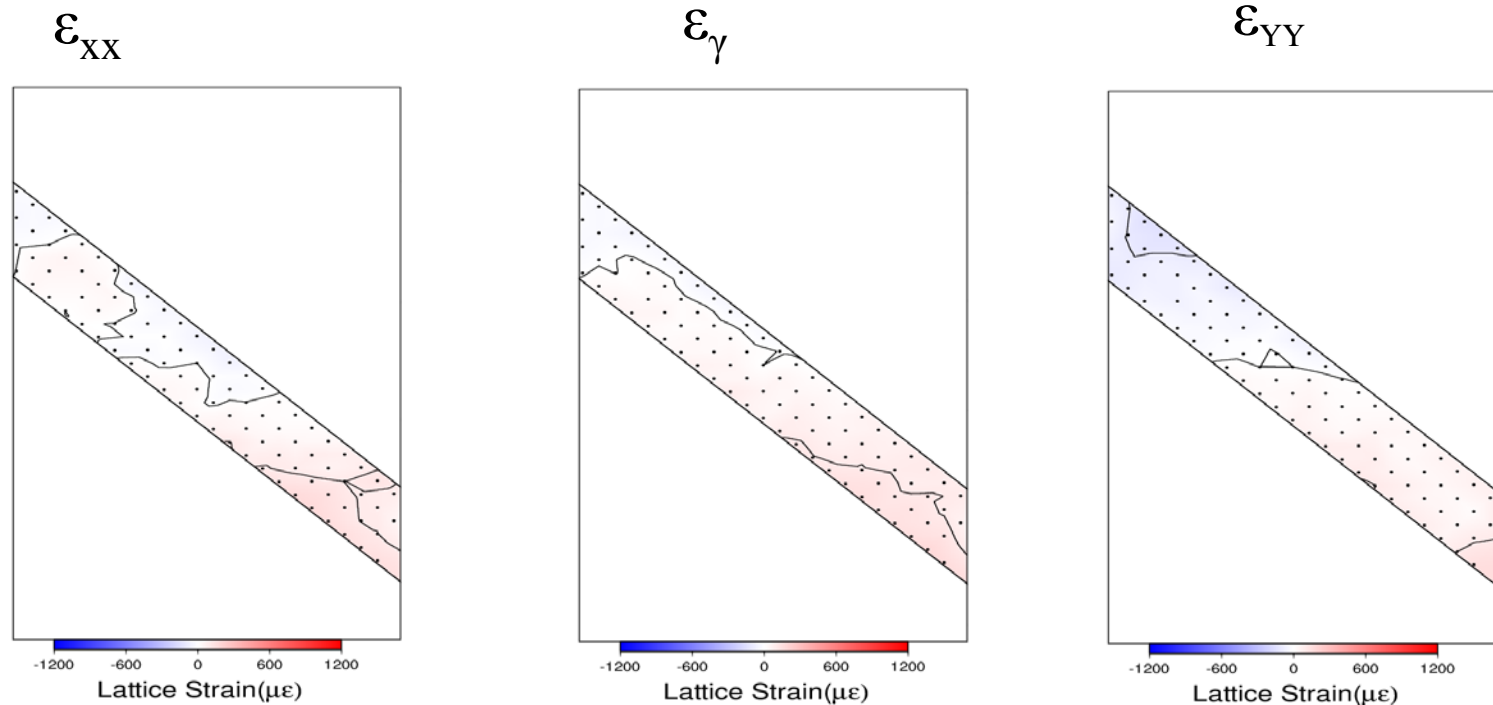
# Strain Distribution at 6200N of Force



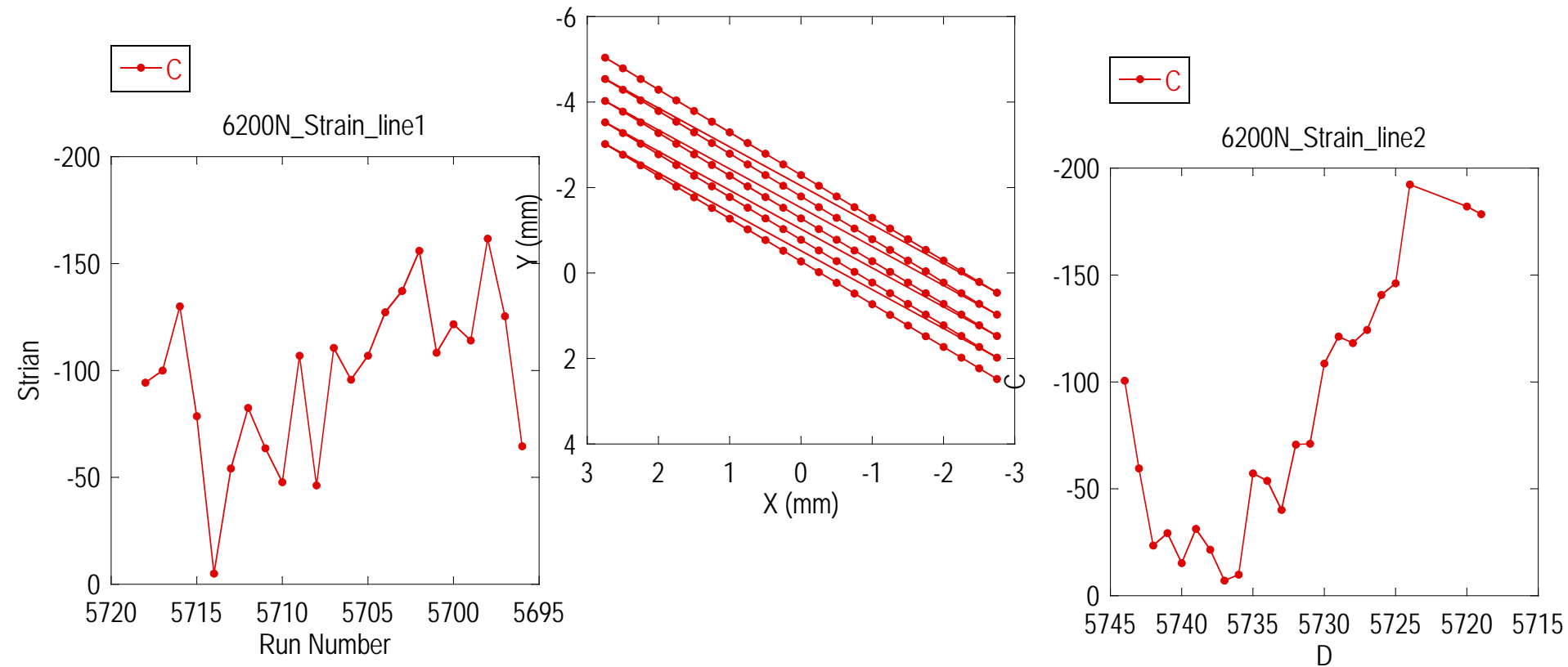
# Strain Distribution at 9000N of Force



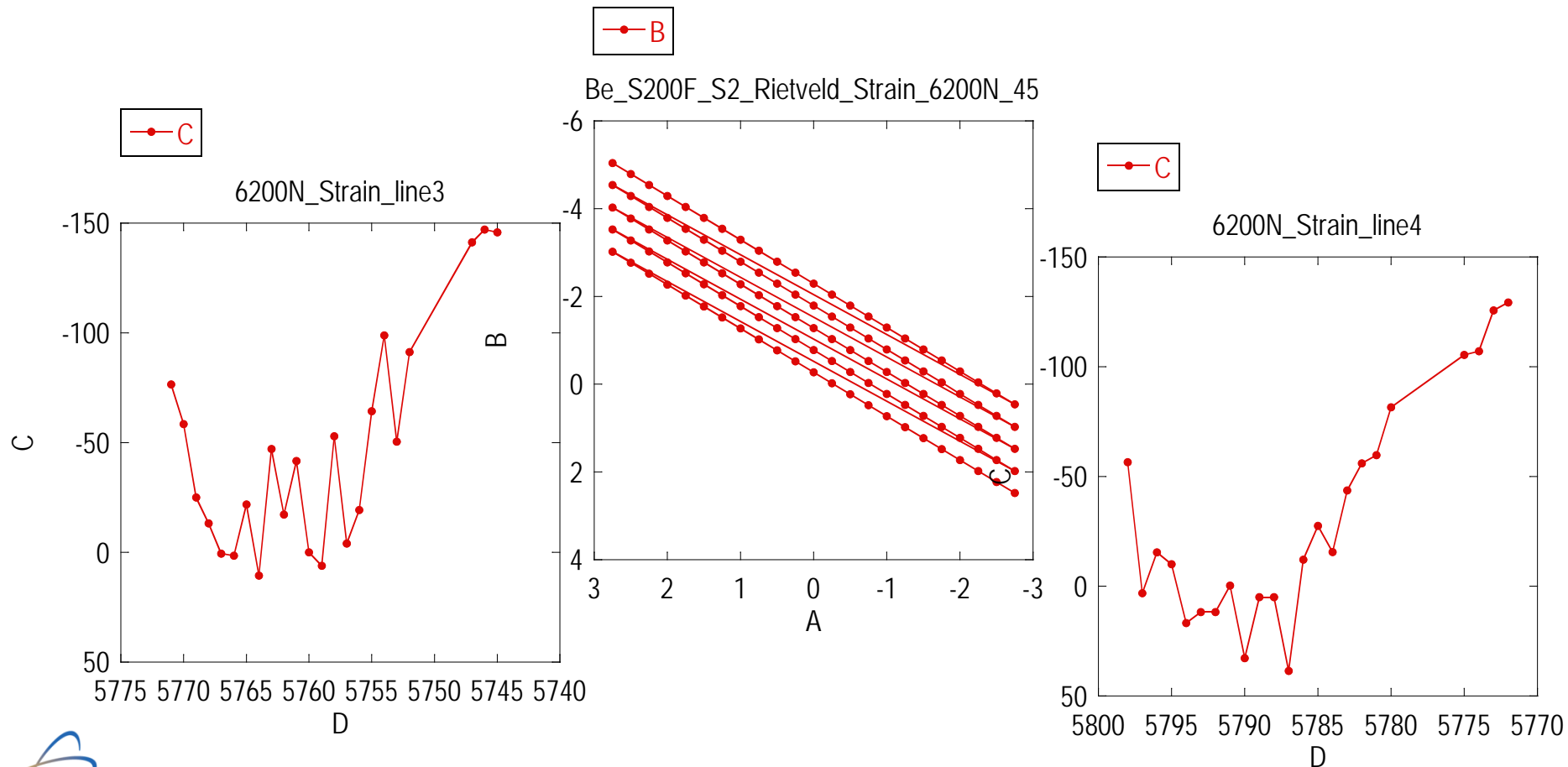
# Strain Distribution at 50N of Force, Post Deformation



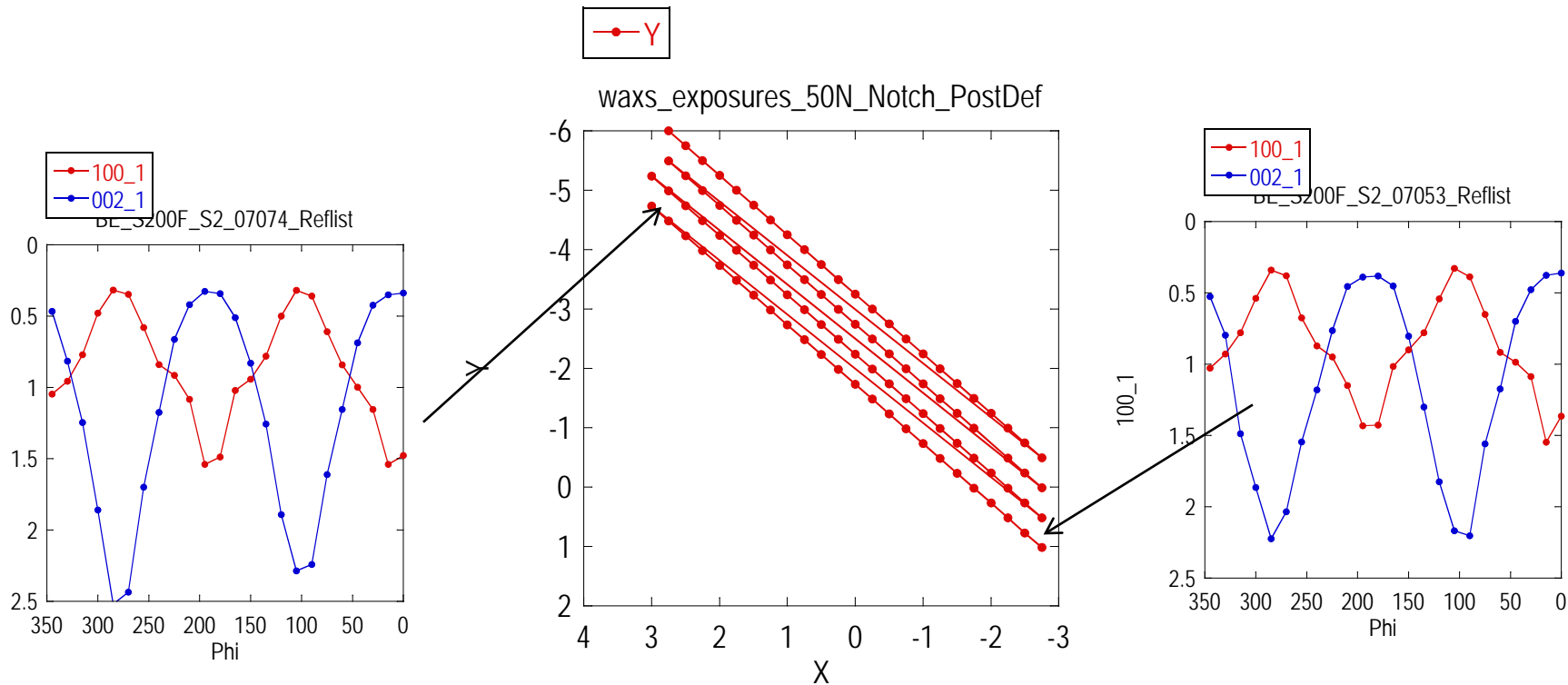
# Strain Distribution at 6200N of Force, Post Deformation



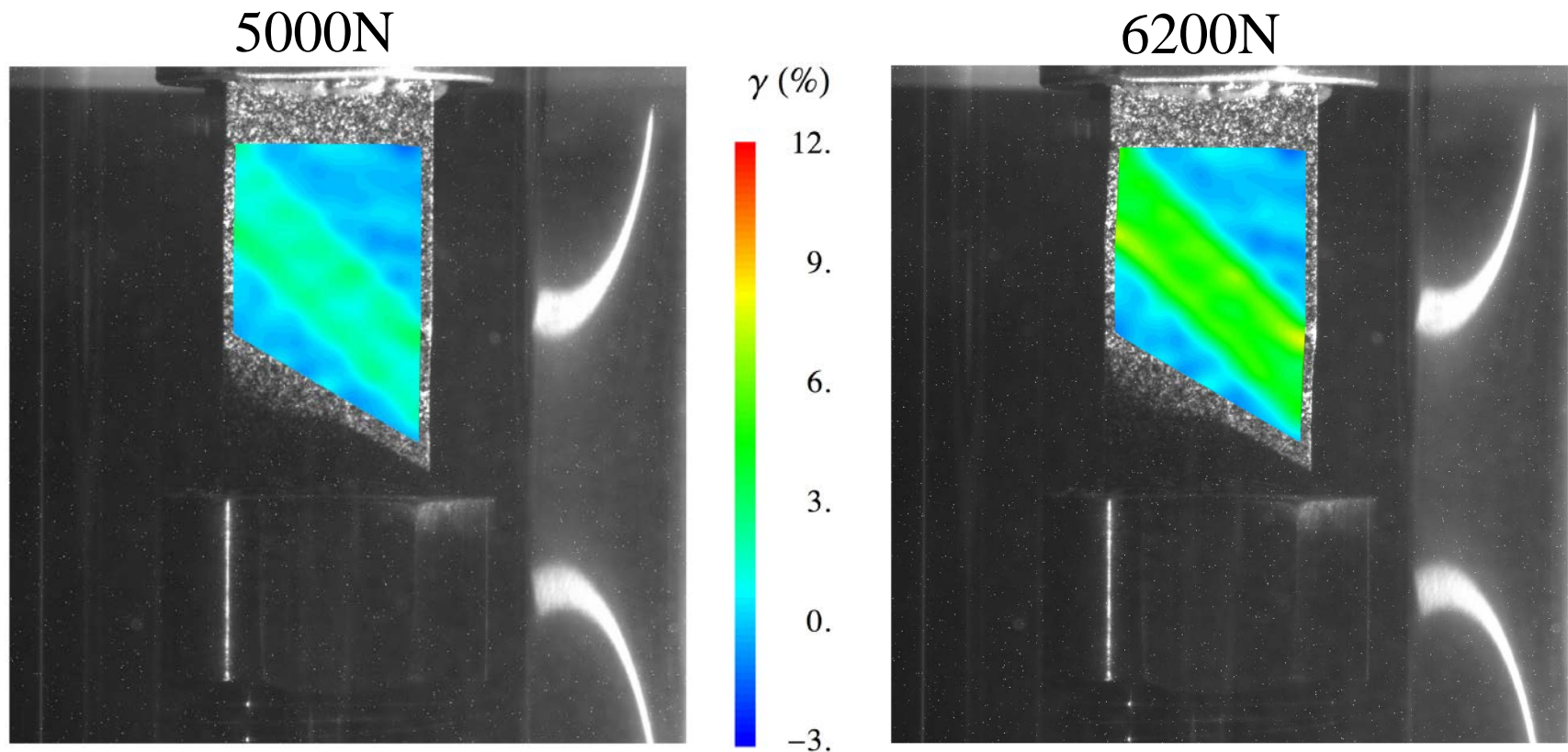
# Strain Distribution at 6200N of Force



# Strain Distribution at 50N of Force, Post Deformation

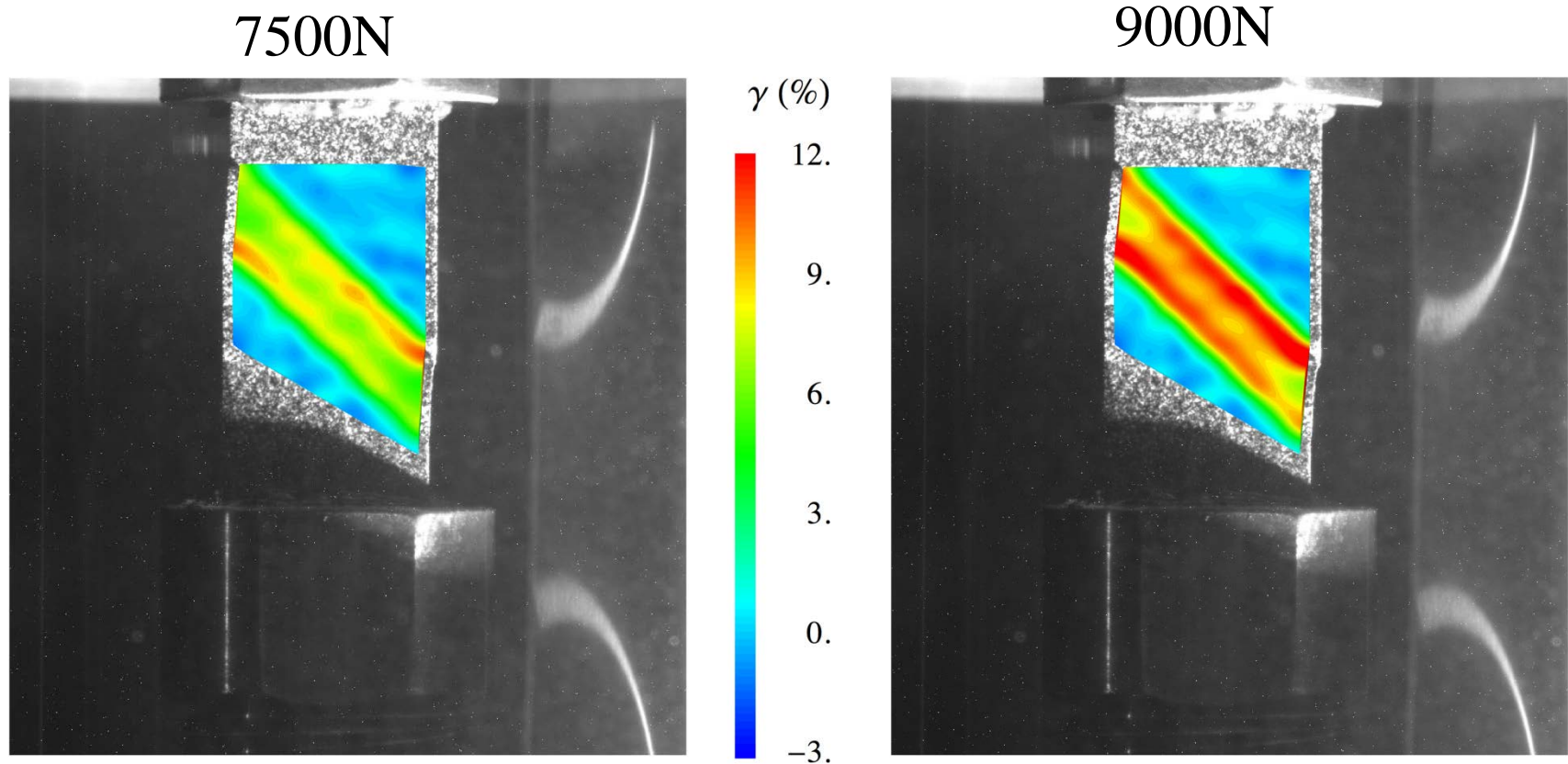


# Digital Image Correlation (DIC)

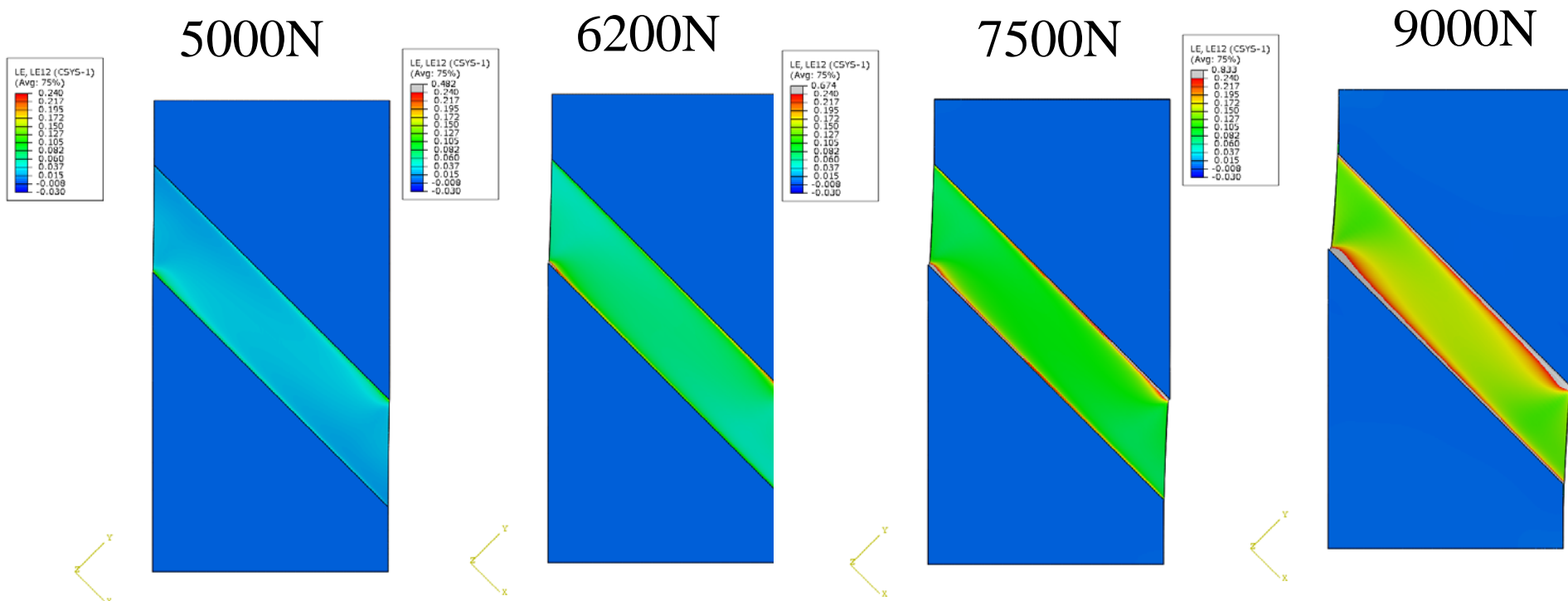




# Digital Image Correlation (DIC)



# Finite Element Model cannot predict change in microstructure



# Summary

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- **X-ray diffraction can be used to monitor evolution of microstructure during deformation.**
- **Deformation twinning in hexagonals has a strong signal in X-ray diffraction.**
- **Data is being used to develop and validate rate dependent polycrystalline plasticity models.**